

ORGANIC EL DEVICE AND METHOD FOR MANUFACTURING THE SAME

Background of the Invention

Field of the invention

5 The present invention relates to an organic EL device and a method of manufacturing the same.

Description of Related Art

10 Recently, in organic EL devices, active matrix organic light emitting diodes (AM-OLED) that can individually control respective pixels are widely used. Each of the pixels typically includes a first thin film transistor (TFT) and a second TFT formed on a transparent substrate, a transparent lower electrode electrically connected to a storage capacitor and a drain electrode of the second TFT, an organic EL region formed on the lower electrode to emit light having a predetermined wavelength, and an opaque upper
15 electrode formed of a material such as aluminum over the whole surface of the transparent substrate.

20 At this point, let us define the AM-OLED that emits light through a back surface of the organic EL region due to the opaque upper electrode as a "back surface emitting AM-OLED." A surface through which light emits as a "back surface" and a surface through which light does not emit is defined as a "front surface."

 Meanwhile, in the back surface emitting AM-OLED, the pixel area is mostly occupied by the first and second TFT and the storage capacitor. Therefore, light emitted from just about 20% of total pixel area is directed toward observers. In other words, the back surface emitting AM-OLED has an aperture ratio of about 20%. It

makes it difficult to achieve a high luminance. More current has to be applied, in order to increase brightness in a low aperture ratio device. This increases power consumption, which is unsuitable for portable display devices.

In order to overcome the problems, the AM-OLED should have a front surface emitting structure which light is emitted through the front surface. In the front surface emitting AM-OLED, the lower electrode should be made of an opaque material, and the upper electrode should be made of a transparent material.

However, if the transparent upper electrode is formed on the organic EL region, the relatively high temperature required for depositing the transparent upper electrode damages the organic EL region. Therefore, it is very difficult to produce a front surface emitting AM-OLED.

U.S. Patent No. 6,046,543 to Bulovic, et al., entitled "*high reliability, high efficiency, integratable organic light emitting devices and methods of producing same.*" describes a method of forming a transparent cathode electrode in order to implement the front surface emitting AM-OLED. U.S. Patent No. 5,981,306 to Burrows, et al., entitled "*method for depositing indium tin oxide layers in organic light emitting devices.*" describes a method of forming indium tin oxide (ITO) at a very low depositing rate in order to implement the front surface emitting AM-OLED. U.S. Patent No. 5,739,545 to Guha, et al., entitled "*organic light emitting diodes having transparent cathode structures.*" describes the front surface emitting AM-OLED implemented using a transparent cathode electrode.

However, such methods are not easy to implement, and demand a long processing time. In addition, it is difficult to control device characteristics. Besides, in

the conventional AM-OLED, as described above, the metal can is used to protect the organic EL region from oxygen and moisture, thus increasing the weight and volume of the AM-OLED as a whole.

SUMMARY OF THE INVENTION

To overcome the problems described above, preferred embodiments of the present invention provide an organic EL device having a high aperture ratio, a high brightness, and consuming less power.

It is another object of the present invention to provide an organic EL device having a high reliability and a lightweight.

In order to achieve the above object, the preferred embodiments of the present invention provide an organic EL device, comprising: a thin film transistor (TFT) array substrate including a first insulating substrate, a TFT and a capacitor formed on the first insulating substrate; and an organic EL substrate including a second insulating substrate, and a transparent electrode, an organic EL layer and a metal electrode, which are sequentially stacked on the second insulating substrate; wherein the TFT is electrically connected to the metal electrode.

The TFT array substrate further includes a conductive interface pad connected to the TFT, the conductive interface pad directly contacting the metal electrode of the organic EL substrate. The organic EL substrate further includes a protection film for shielding oxygen and moisture externally coming into. The protection film is formed by repeatedly depositing a SiNx layer and a SiO₂ layer at least one time. The TFT array substrate and the organic EL substrate are sealed by a UV-curable agent. The TFT array substrate further includes a conductive interface pad connected to the TFT and a

conductive bump pad formed on the conductive interface pad, the conductive bump pad contacting the metal electrode of the organic EL substrate by a conductive bonding agent. The conductive bonding agent is an anisotropic conductive film (ACF). The anisotropic conductive film also shields off the external oxygen and moisture. The TFT array substrate further includes a conductive interface pad and a conductive bump pad formed on the conductive interface pad, and the organic EL substrate further includes a polymer bump, wherein the conductive bump pad contacts a portion of the metal electrode corresponding to the polymer bump by a conductive bonding agent.

The preferred embodiments of the present invention further provide a method of manufacturing an organic EL device, comprising: forming a thin film transistor (TFT) array substrate including a TFT and a capacitor formed on a first insulating substrate; forming an organic EL substrate including a transparent electrode, an organic EL layer and a metal electrode sequentially formed on a second insulating substrate; and sealing the TFT array substrate and the organic EL substrate to electrically connect the TFT of the TFT array substrate to the metal electrode of the organic EL substrate.

Using a method of manufacturing the organic EL device according to the preferred embodiments of the present invention, an organic EL device having a high aperture ratio, a high luminance, and a low power consumption can be obtained. In addition, an organic EL device having a high reliability and a lightweight can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following descriptions taken in

conjunction with the accompanying drawings, in which like reference numerals denote like parts:

Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 are processing views illustrating a process of manufacturing a thin film transistor (TFT) array substrate according to a first preferred embodiment of the present invention;

Fig. 17 is a cross-sectional view illustrating an organic EL substrate according to the first preferred embodiment of the present invention;

Fig. 18 is a cross-sectional view illustrating an organic EL device according to the first preferred embodiment of the present invention;

Fig. 19 is a circuit diagram illustrating an equivalent circuit of one pixel of the organic EL device according to the preferred embodiments of the present invention;

Fig. 20 is a cross-sectional view illustrating a process of assembling the organic EL device according to the first preferred embodiment of the present invention;

Fig. 21 is a perspective view illustrating a TFT array substrate according to a second preferred embodiment of the present invention;

Figs. 22, 23, 24 and 25 are cross-sectional views illustrating a process of manufacturing an organic EL substrate according to the second preferred embodiment of the present invention;

Figs. 26 and 27 are cross-sectional views illustrating a process of assembling the TFT array substrate and the organic EL substrate according to the second preferred embodiment of the present invention;

Figs. 28, 29 and 30 are cross-sectional views illustrating a process of manufacturing an organic EL substrate according to a third preferred embodiment of the

present invention; and

Figs. 31 and 32 are cross-sectional views illustrating a process of assembling the TFT array substrate and the organic EL substrate according to the third preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference will now be made in detail to preferred embodiments of the present invention, example of which is illustrated in the accompanying drawings.

A configuration of an organic EL device according to the preferred embodiment of the present invention will be explained through a process of manufacturing the organic EL device. In order to manufacture the organic EL device, a TFT array substrate 500 in Fig. 15 supplying a display power to the organic EL region and an organic EL substrate 900 in Fig. 17 including an organic EL region are respectively manufactured and then are assembled.

First, a process of manufacturing the TFT array substrate 500 according to a first preferred embodiment of the present invention is explained with reference to Figs. 1 through 16 and 19, and a process of manufacturing the organic EL substrate 900 according to the first preferred embodiment of the present invention is explained with reference to Fig. 17. Thereafter, a process of assembling the TFT array substrate and the organic EL substrate according to the first preferred embodiment of the present invention is explained with reference to Figs. 18 and 20.

In Figs. 1, 3, 5, 7, 9, 11, 13, 15, left portions show cross-sectional views taken long line A-A of Figs. 2, 4, 6, 8, 10, 12, 14, 16, right portions show cross-sectional views taken long line B-B of Figs. 2, 4, 6, 8, 10, 12, 14, 16, respectively.

Referring to Fig. 19, in order to form one unit pixel on the TFT array substrate 500 on a base substrate 400 in Fig. 1, two thin film transistors (TFTs) 100 and 200, a storage capacitor 300, gate lines 430 supplying a bias voltage to turn on the TFTs, data lines 450 to which an image signal encoded from an image signal processing apparatus (e.g., VGA card), and common power lines 460 are formed.

First, in order to manufacture the first TFT 100 and the second TFT 200, as shown in Figs. 1 and 2, a buffer layer 410 is formed on the whole surface of the base substrate or the first insulating substrate 400 to a predetermined thickness. The buffer layer 410 serves to prevent the first TFT 100, the second TFT 200, and the storage capacitor 300 that will be formed in a subsequent process from ions coming from the base substrate 400. For example, when the base substrate 400 is made of glass, the buffer layer 410 prevents that ions such as Na^+ and K^+ of glass are diffused into the first TFT 100, the second TFT 200, and the storage capacitor 300.

An amorphous silicon layer is deposited on the buffer layer 410. Even though not shown, the amorphous silicon layer is subject to an annealing process, for example, a laser annealing, to form a polycrystalline silicon layer. The reason to form the polycrystalline silicon layer is that the polycrystalline silicon layer has superior electron mobility to the amorphous silicon layer. Instead of depositing and annealing the amorphous silicon layer to form the polycrystalline silicon layer, the polycrystalline silicon layer may be deposited directly on the buffer layer 410 through, for example, a chemical vapor deposition (CVD) technique. Therefore, the polycrystalline silicon layer is patterned into first and second semiconductor layers 110 and 210 of an island shape.

In more detail, a photoresist is coated on the polycrystalline silicon layer using

for example, a spin coating technique, and is subject to a light exposure to form photoresist patterns on a location corresponding to the first and second semiconductor layers 110 and 210. Using the photoresist patterns as a mask, the polycrystalline silicon layer is wet- or dry-etched to form the first semiconductor layer 110 and the second semiconductor layer 210. The photoresist patterns are removed.

Subsequently, as shown in Figs. 3 and 4, a gate insulating layer 420 is formed over the whole surface of the base substrate to cover the first and the second semiconductor layers 110 and 210. The gate insulating layer 420 serves to insulate the first and second semiconductor layers 110 and 210, respectively, from first and second gate electrodes of the first and second TFTs 100 and 200 that will be formed in a subsequent process.

Thereafter, a first metal layer is deposited on the gate insulating layer 420 using, for example, a sputtering technique to a predetermined thickness. The first metal layer comprises a metal such as aluminum (Al) and aluminum-neodymium alloy (Al:Nd). As shown in Figs. 5, 6 and 19 the first metal layer is patterned to form a first gate electrode 120 of the first TFT 100, a second gate electrode 220 of the second TFT 200, a first capacitor electrode 310 of the storage capacitor 300, and a gate line 430. Subsequently, an n-type or a p-type impurity is ion-implanted into the first and second semiconductor layers 110 and 220 to form a first source region 130 and a first drain region 140 of the first TFT 100 and a second region 240 source and a second drain region 230 of the second TFT 200.

In more detail, on a portion of the gate insulating layer 420 corresponding to the first semiconductor layer 110, the first gate electrode 120 having an area size smaller

than the first semiconductor layer 110 is formed. The gate line 430 is arranged in a transverse direction spaced apart from the first semiconductor layer 110 and is connected to the first gate electrode 120. At this point, the first semiconductor layer 110 includes the source region 130 and the drain region and 140, respectively, formed on both end portions thereof. The first capacitor electrode 310 is formed between the first gate electrode 120 and the second gate electrode 220 in such a way that it is spaced apart from the drain region 140 of the first semiconductor layer 110 and is connected to the second gate electrode 220. On a portion of the gate insulating layer 420 corresponding to the second semiconductor layer 210, the second gate electrode 220 having a smaller area size than the second semiconductor layer 210 is formed. At this point, the second semiconductor layer 210 includes the drain region 230 and the source region 240, respectively, formed on both end portions thereof.

As shown in Figs. 7 and 8, an interlayer insulator 440 is formed over the whole surface of the base substrate 400 to cover the first and second gate electrodes 120 and 220, and the first capacitor electrode 310. The interlayer insulator 440 serves to insulate the first and second gate electrodes 120 and 220 from first source and drain electrodes 182 and 184 and second source and drain electrodes 282 and 284, which will be formed in a subsequent process. A portion of the interlayer insulator 440 corresponding to the first capacitor electrode 310 serves as a dielectric layer of the storage capacitor 300.

As shown in Figs. 9 and 10, the interlayer insulator 440 includes a first source contact hole 172 and a first drain contact hole 174 and a second drain contact hole 272 and source contact hole 274. The first source and drain contact holes 172 and 174 are

formed at locations corresponding to the first source and drain regions 130 and 140, and the second drain and source contact holes 272 and 274 are formed at locations corresponding to the second drain and source regions 230 and 240. The interlayer insulator 440 further includes a capacitor contact hole 320 at a location corresponding to a portion of the first capacitor electrode 310 adjacent to the first drain region 140.

Subsequently, a second metal layer is deposited on the interlayer insulator 440 using, for example, a sputtering technique. As shown in Figs. 11, 12 and 19, the second metal layer is patterned to form a first source electrode 182 and a second drain electrode 184 of the first TFT 100, a second source electrode 282 and a second drain electrode 284 of the second TFT 200, a second capacitor electrode 330 of the storage capacitor 300, a data line 450, and a common power line 460.

The data line 450 is arranged in a perpendicular direction to the gate line 430 and is connected to one end portion of the first source electrode 182. The other end portion of the first source electrode 182 overlaps over one end portion of the first gate electrode 120. The first source electrode 182 is electrically connected to the first source region 130 through first source contact hole 172. One end portion of the first drain electrode 184 overlaps over the other end portion of the first gate electrode 120, and the other end portion of the first drain electrode 184 overlaps over an end portion of the first capacitor electrode 310. The first drain electrode 184 is electrically connected to the first drain region 140 and the first capacitor electrode 310, respectively, through the first drain contact hole 174 and the capacitor contact hole 320. The common power line 460 is arranged in a perpendicular direction to the gate line 430 and is opposite to the data line 450. The second capacitor electrode 330 is connected to the common power line

460 and overlaps the first capacitor electrode 310. The second drain electrode 284 has one end portion overlapping over one end portion of the second gate electrode 220, and second source electrode 282 has one end portion overlapping over the other end portion of the second gate electrode 220 and the other end portion extending from the common power line 460. The second drain electrode 284 is electrically connected to the second drain region 230 through the second drain contact hole 272, and the second source electrode 282 is electrically connected to the second source region 240 through the second source contact hole 274.

Subsequently, as shown in Figs. 13 and 14, a planarization film 470 is formed over the whole surface of the base substrate 400 to cover the first source and drain electrodes 182 and 184, the second source and drain electrodes 282 and 284, the second capacitor electrode 330, the data line 450, and the common power line 460. The planarization film 470 includes a third drain contact hole 475 (see Fig. 15) at a location corresponding to a portion of the second drain electrode 284

Finally, as shown in Figs. 15 and 16, a conductive material layer is deposited on the planarization film 470 and is patterned to form an interface pad 480. The interface pad 480 is electrically connected to the second drain electrode 284 through the third drain contact hole 475. This completes the TFT array substrate 500.

The manufactured TFT array substrate 500 is then assembled with the organic EL substrate 900.

Fig. 17 is a cross-sectional view illustrating the organic EL substrate 900 according to the first preferred embodiment of the present invention. First, a protection film 920 is formed on a transparent substrate or second insulating substrate 910.

Preferably, the protection film is made of SiO_2 or SiNx . The protection film 920 serves to shield oxygen and moisture coming into through the transparent substrate 910. That is, the protection film 920 plays the same role as the conventional metal can. Thereafter, a transparent electrode 930 is deposited on the protection film 920 to a predetermined thickness. Preferably, the transparent electrode 930 is made of indium tin oxide or indium zinc oxide. Subsequently, an organic EL layer 940 is formed on the transparent electrode 930. The organic EL layer 940 includes one of a red organic EL material, a green organic EL material, and a blue organic EL material. Finally, a metal electrode 950 is formed on the organic EL layer 940. Therefore, the organic EL substrate 900 according to the first preferred embodiment of the present invention is completed.

Figs. 18 and 20 are cross-sectional views illustrating the organic EL device in which the TFT array substrate 500 is assembled with the organic EL substrate 900 according to the first preferred embodiment of the present invention.

In order to assemble the TFT array substrate 500 and the organic EL substrate 900, for example, in a vacuum chamber (not shown), the TFT array substrate 500 is aligned with the organic EL substrate 900 to face the interface pad 480 of the TFT array substrate 500 toward the metal electrode 950 of the organic EL substrate 900. Thereafter, an UV-curable agent 960 is coated on the side of the TFT array substrate 500 and the organic EL substrate 900 as shown in Fig. 20 and then is cured by an ultraviolet ray. When the TFT array substrate 500 and the organic EL substrate 900 that the UV-curable agent is cured come out of the vacuum chamber, the TFT array substrate 500 and the organic EL substrate 900 are closely stuck to each other due to a

vacuum pressure, so that an electric current can flow from the interface pad 480 of the TFT array substrate 500 to the metal electrode 950 of the organic EL substrate 900.

Fig. 21 is a perspective view illustrating a TFT array substrate 500 according to a second preferred embodiment of the present invention. The TFT array substrate 500 includes a bump pad 490 in addition to a configuration of the TFT array substrate 500 of Fig. 16. At this point, the interface pad 480 is made of a conductive resin, a metal alloy, or a conductive metal such as Al, Pd, Au, Ti, TiW, NiCr, Cr, Nd, AlNd, and Pt, and has a thickness of about 300 Å to about 20000 Å. The bump pad 490 is formed using an electroplating technique, a non-electrolysis plating technique, a sputtering technique, a spin coating technique, or a chemical vapor deposition (CVD) technique. The bump pad 490 comprises Ni, Au, PbSn, In, or polymer.

The TFT array substrate 500 of Fig. 21 is assembled with a organic EL substrate 600 in Fig. 25. Figs. 22, 23, 24 and 25 are cross-sectional views illustrating a process of manufacturing the organic EL substrate 600 according to the second preferred embodiment of the present invention.

First, as shown in Fig. 22, a transparent electrode is formed on a transparent substrate 610 to a predetermined thickness. The transparent electrode 620 is made of a transparent material such as indium tin oxide (ITO) or indium zinc oxide (IZO).

Thereafter, as shown in Fig. 23, an organic EL layer 630 is formed on the transparent electrode 620 using a shadow mask 640. The organic EL layer 630 includes one of a red organic EL material, a green organic EL material and a blue organic EL material. The shadow mask 640 includes an opening portion 645. The opening portion 645 is formed at a location corresponding to the organic EL layer 630.

Subsequently, as shown in Fig. 24, a conductive metal layer is deposited on the organic EL layer 630 through the opening portion 655 of the shadow mask 650 to form a metal electrode 660.

As shown in Fig. 25, a protection film 670 is formed to overlap both end portions of the metal electrode 660 using a photolithography technique, exposing an upper surface of the metal electrode 660.

Next, as shown in Fig. 26, an anisotropic conductive film (ACF) 680 is formed over the whole surface of the transparent substrate 610 to a predetermined thickness. The anisotropic conductive film 680 has both adhesive force and conductivity. In other words, the anisotropic conductive film 680 is configured in a way that conductive particles are finely arranged among adhesive materials, and therefore, when the anisotropic conductive film 680 is pressurized, electrons can flow through the conductive particles. Such an anisotropic conductive film 680 is used to enable an electric current to flow from one conductive material to another conductive material by an attachment method other than a soldering method.

The organic EL substrate 600 on which the anisotropic conductive film 680 is formed is aligned with the TFT array substrate 500 to face the anisotropic conductive film 680 of the organic EL substrate 600 toward the bump pad 490 of the TFT array substrate 500.

Then, as shown in Fig. 27, the TFT array substrate 500 and the organic EL substrate 600 are heated, pressurized, and UV-treated to be glued to each other. As a result, not only the TFT array substrate 500 and the organic EL substrate 600 are firmly stuck to each other, but also electrons can travel from the bump pad 490 to the metal

electrode 660.

A portion of the anisotropic conductive film 680 where electrons do not move serves to shield the organic EL device from oxygen and moisture. That is, the portion of the anisotropic conductive film 680 where a movement of electrons does not occur
5 plays the same role as the conventional metal can.

When the TFT array substrate 500 and the organic EL substrate 600 are assembled using the anisotropic conductive film 680, a much stronger adhesive force can be obtained than using the UV-curable agent 960 of Fig. 20. In addition, electric characteristics can be improved by reducing such problems as a signal delay caused by
10 a contact resistance between the interface pad 480 and the metal electrode 950 of Fig. 20.

Figs. 28, 29 and 30 are cross-sectional views illustrating a process of manufacturing an organic EL substrate according to a third preferred embodiment of the present invention. First, a transparent material layer is deposited on a transparent
15 substrate 710 and patterned to form a transparent electrode 720. Preferably, the transparent substrate 710 is made of glass, and the transparent electrode 720 is made of indium tin oxide (ITO) or indium zinc oxide (IZO).

Thereafter, a polymer bump 730 is formed on the transparent electrode 720. Preferably, the polymer bump 730 is made of photoresist, acryl, or polyimide. The
20 polymer bump 730 is formed at a location adjacent to a location 731 defined by a dotted line where an organic EL layer will be formed in a subsequent process. The polymer bump 730 has a higher height than a summation of a height of the organic EL layer and a height of a metal electrode to be formed in subsequent process.

Subsequently, as shown in Fig. 29, a shadow mask 740 is aligned with the array substrate so that the shadow mask 740 may be laid across the polymer bump 730. The shadow mask 740 includes an opening portion 745 that is somewhat wider in area size than the location 731, and a portion of the opening portion 745 of the shadow mask 740 is arranged on a portion of the polymer bump 730. Then, an organic EL material is deposited on the transparent electrode 720 through the opening portion 745 of the shadow mask to form an organic EL layer 750. The organic EL layer 750 overlaps a portion of the polymer bump 730 and thus has a step portion. The organic EL layer 750 has a somewhat larger area size than substantially needed.

Next, as shown in Fig. 30, a metal layer is deposited on the organic EL layer 750 through the opening portion 745 of the shadow mask 740 to form a metal electrode 760. The anode electrode 760 has the same shape and area size as the organic EL layer 750.

Meanwhile, for the sake of a precise process, it is preferable that the shadow mask 740 be as thin as possible. However, a thinner shadow mask tends to bend more. As a result, it is very difficult to secure a pattern area of the organic EL layer 750 and the metal electrode 760. For this reason, a portion of the shadow mask 740 is laid across the polymer bumper 730.

As described above, a portion of the organic EL layer 750 overlaps a portion of the polymer bump 730. This is to increase an adhesive force between the metal electrode 760 and the bump pad 490 and to prevent a short circuit between two adjacent metal electrodes without an additional protection film.

Subsequently, as shown in Fig. 31, an anisotropic conductive film 770 is formed

over the whole surface of the organic EL substrate 700 to cover the metal electrode 760. Then, the organic EL substrate 700 is aligned with the TFT array substrate 500 of Fig. 21 to face the anisotropic conductive film 770 of the organic EL substrate 700 toward the bump pad 490 of the TFT array substrate 500.

5 Then, as shown in Fig. 32, the TFT array substrate 500 and the organic EL substrate 700 are heated, pressurized, and UV-treated to be glued to each other. As a result, not only the TFT array substrate 500 and the organic EL substrate 700 are firmly stuck to each other, but also electrons can travel from the bump pad 490 to the metal electrode 760.

10 As another example, a solder may be coated on the bump pad 490 and then melted to solder the bump pad 490 of the TFT array substrate 500 and the metal electrode 760 of the organic EL substrate 700.

As described herein before, using a method for manufacturing the organic EL device according to the preferred embodiments of the present invention, an organic EL
15 device having a high aperture ratio, a high luminance, and consuming less power can be obtained. In addition, an organic EL device having a high reliability and a lightweight can be obtained.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the
20 foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.